

# **Implementing CWMS in the Missouri River Region**

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## **A. Introduction**

The Corps Water Management System (CWMS) is the automated information system (AIS) supporting the Army Corps of Engineers' (Corps) water management mission. CWMS provides data collection, processing, decision support modeling, data dissemination, and graphics tools for each local office to effectively execute the water management mission specific to its office.<sup>1</sup>

CWMS is currently being implemented in the Missouri River Basin in the Omaha District water control office (NWO), the Kansas City District water control office (NWK) and the Missouri River water management office (MRR). CWMS was developed, and is experiencing on-going development, by the Corps' Hydrologic Engineering Center (HEC) with design and funding input from all the Corps' water control offices.

## **B. Implementation**

Three offices are responsible for the Missouri River Region water management activities. MRR is responsible for the operation and regulation of the Missouri River mainstem projects of the entire Missouri River Basin. NWO is responsible for the operation and regulation of Missouri River tributary projects from the headwaters of the Missouri River to Rulo, Nebraska. NWK is responsible for the operation and regulation of Missouri River tributary projects from Rulo, Nebraska to the mouth of the Missouri River at St. Louis, Missouri (refer to Figure 1).

The three offices' water management responsibilities dovetail. For each office to complete its mission effectively, various data must be shared on a near-as-possible real-time basis. These data consist primarily of river stage and flow and reservoir elevation data as well as river forecast results. Back in the late 1970's all three offices were working from a common database called the Missouri River Automated Database System (MRADS). Each office had dial-in capabilities to access and manipulate data specific to its control mission. As computer technology increased in the 1980's and 1990's, the offices began to develop their own databases. Sharing of the data and forecast results was still maintained, but maintenance of three separate databases and sharing of data proved to be a bigger and bigger manpower effort.

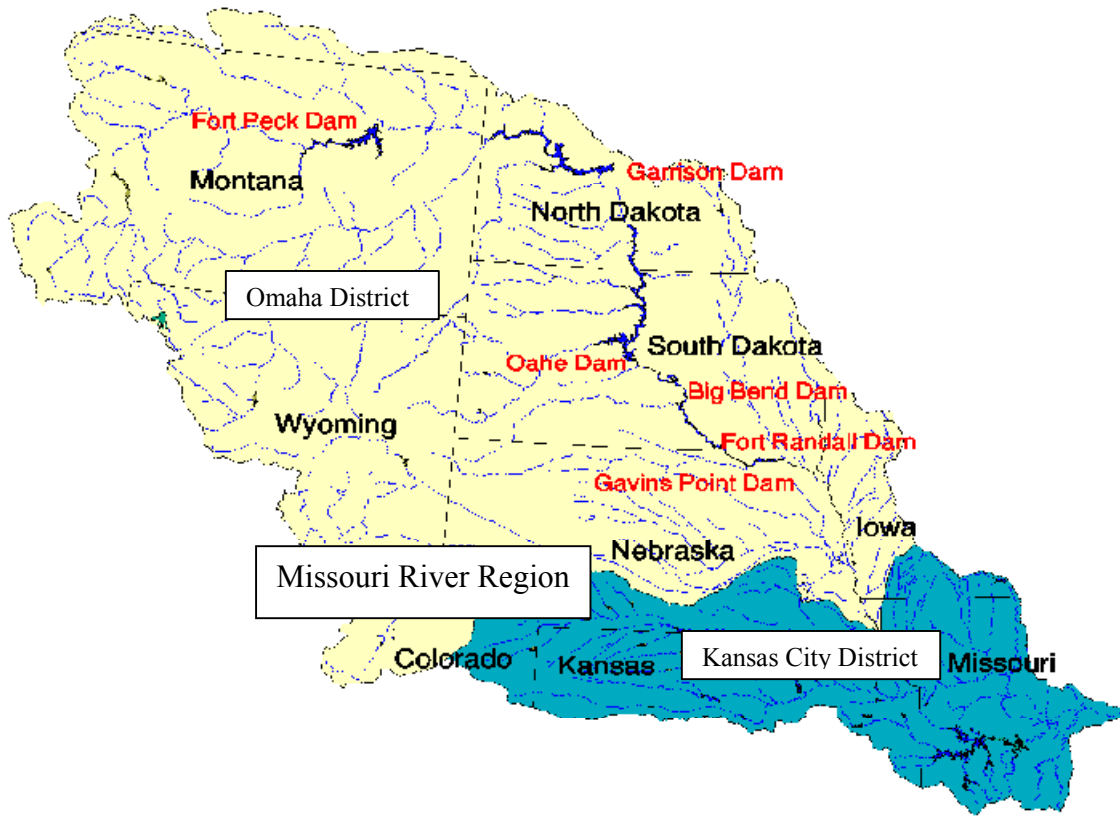


Figure 1 – Missouri River Region and Omaha and Kansas City District boundaries.

With the implementation of CWMS, the offices saw an opportunity to create a regional corporate database. The corporate database would benefit all the offices by 1) reducing manpower effort in the area of screening raw data; 2) clearing up confusion regarding differing flows (for the same stage) at key forecasting locations; 3) increasing customer satisfaction by providing consistent, instead of conflicting, data; 4) increasing inter-office communication between the three offices regarding responsibilities and technical assistance; and 5) being an integral part of establishing a Continuity Of Operations Plan (COOP) plan for the three offices.

### **C. Office Responsibilities**

Determination of office responsibilities in support of the regional corporate database involved: 1) acquisition of National Environmental Satellite, Data and Information System (NESDIS) GEostationary Satellite (GOES) data, 2) acquisition of non-GOES data, 3) decoding of GOES data, 4) station naming conventions, 5) storing of data to the CWMS Oracle database, 6) acquisition and updating of rating curves and measurements (shifts), 7) interactive data screening, and 8) sharing real-time model results.

1. Acquisition of GOES data. Each office has at least one workstation dedicated to collecting raw GOES data. The Omaha District has two DOMestic SATellite (domsat) machines, the Kansas City District has an LRGS (local readout ground station) domsat, and the Missouri River Region office has a DRGS (direct readout ground station). This setup is considered very favorable for COOP purposes. All four of the machines are configured to capture all the GOES station data in the Missouri River Basin. In addition, the MRR DRGS is a viable data collection option should something happen to the main NESDIS receive site in Wallops Island that feeds the domsats, such as the lightning strike of late March 2003.
2. Acquisition of non-GOES data. Each office acquires information from various sources – National Weather Service (NWS), Missouri River mainstem powerhouses, U.S. Bureau of Reclamation (USBR), U.S. Geological Survey (USGS), Natural Resource Conservation Service (NRCS), local basin alert systems, state/county/local government entities, and private citizens. While all these data need to be stored in the CWMS Oracle database, only a portion of this information needs to be disseminated to all three offices in the basin (for COOP purposes).
3. Decoding of GOES data. All GOES data is (will be) decoded using the DECODES software, developed by Mike Maloney of Ilex Engineering. Currently, the MRR and NWK offices are using DECODES exclusively. The NWO office still has the NWS goesit decoding routine running in conjunction with DECODES. All the 541 GOES stations in the region have been divided out among the three offices, based on their usage of the data. The stations are identified with the office prefix (e.g. MRR-ACIA, NWO-RESA and NWK-CHMO). Each office is responsible for maintaining the decodes for its stations. On a daily basis, via a crontab, each office will run a script that exports its stations' configurations from its DECODES database to a single XML-format file and copies that file to a common directory. Each office, again via a crontab, runs a daily script to copy the other two office's XML-format files and imports the station configurations into its DECODES database. This procedure follows COOP guidelines and ensures that no one location is solely responsible and/or needed to decode the GOES data. In addition, the process spreads out the decoding expertise to the three offices.
4. Station naming conventions. The naming convention of the stations will be based on a four-letter identification (in some cases, only three letters). The four-letter identification convention was initially started with the MRADS database. The offices discussed adopting a more nationally- and Federal agency-accepted naming convention. We investigated using the NWS SHEF id, the USGS station id and the GOES id, but found that not all our stations applied in every case. It was finally decided to stay with our own tried and true naming convention of using the first two letters to define the location and the last two letters to define the state (e.g. ROIA – East Nishnabotna River at

Red Oak, IA). The full CWMS name (with subCWMS id) for this station would then be ROIA-Red Oak-East Nishnabotna.

5. Initial storing of data to the CWMS Oracle database. All three offices agreed on a specific naming convention for the stations. This was essential for the corporate database concept to succeed. The offices also agreed on a common parameter naming convention to be used in the DECODES database.
6. Rating curves and shifts. The GOES stations have been divided up between the three offices. Each office is responsible for acquiring and maintaining current rating curves and associated rating curve shifts and storage tables for those stations. Each office is to access the appropriate USGS database on a regular basis (weekly during high runoff/flooding periods, less often during low runoff periods), download the information and populate HEC-DSS files. Those files will be copied to the common directory for the other offices to obtain for COOP purposes (e.g. nwk-rating.dss, nwo-measure.dss, mrr-discharge.mac). MRR is currently experimenting with maintaining the rating curves and shifts on the CWMS Oracle database rather than in HEC-DSS files. Once completed, it is hoped that this function will eventually be added into the CWMS package as a “betterment”.
7. Reviewing/editing raw data. Each of the three offices is responsible for reviewing and editing the raw data from its stations. Presently, each office is reviewing and editing all data that it needs for regulation purposes. This has resulted, in some cases, the data for one station being reviewed and edited by all three offices. Under the corporate database scheme, each station will get reviewed and edited once by one office. The resulting reviewed and edited data will be shared among all three offices.
8. Sharing of forecast model results. CWMS real-time model results will be posted to all databases. As previously mentioned, the regulation responsibilities of the three offices dovetail. It is vital that forecast results from upstream basins, regardless of what office runs the forecast, be available for usage in the forecast models for the basin further downstream.

#### **D. Master Station Database**

Between the three offices, data from 542 GOES stations are collected and decoded from each of the four GOES data sources. Over 1200 parameters (not including battery voltage) are stored for these 542 stations. Maintaining current information for all these stations and making sure that any changes made to a station make it through the entire database has proved to be an extremely time-intensive task; therefore, a CWMS master station database was determined to be necessary. The master station database was initially started as an Excel spreadsheet that contained all pertinent information regarding a station:

- a. Existing name
- b. NWS Handbook 5 name
- c. USGS id
- d. GOES id
- e. USBR id
- f. CWMS id
- g. SubCWMS id
- h. Long description
- i. NWS local office
- j. Latitude
- k. Longitude
- l. Transmit time
- m. Transmit interval
- n. Current rating or storage curve
- o. Parameter (ex. stage, elevation, precipitation)
- p. Minimum questionable
- q. Maximum questionable
- r. Minimum rejected
- s. Maximum rejected
- t. Parameter interval
- u. Parameter offset (related to transmit time)

Development of the CWMS master station database began in late March of this year and is still continuing. MRR has contracted with a former employee to develop a graphics user interface (GUI) that will populate an Oracle master station table from the Excel spreadsheet. The Oracle master station table will in turn populate all the respective tables in the CWMS Oracle database. Triggers will be implemented to cross-check the CWMS Oracle tables against the master station table and vice versa to ensure that all changes, whether they be made in the CWMS Oracle tables or in the master station table, are noted throughout. The GUI will allow the user to export the master station table to an Excel-readable format so that the user can use this information outside of the CWMS Oracle database.

Initially, the Oracle master table is being designed to create the following files used in CWMS:

1. Shefit criteria: this file is used to write the decoded random and self-timed GOES data to Oracle (see example). Note that a shefit criteria file is required for every data stream.

```
CE42AAD0.HG.RZZ.0=ACIA-Atlantic-East Nishnabotna.Stage.Inst.0.0.$Stream-raw;TZ=UTC;
DLTime=false;Units=ft
CE42AAD0.PP.RZZ.0=ACIA-Atlantic-East Nishnabotna.Precip.Inst.0.0.$Stream-raw;TZ=UTC;
DLTime=false;Units=in
CE42AAD0.HG.RZZ.1001=ACIA-Atlantic-East Nishnabotna.Stage.Inst.0.0.$Stream-raw;TZ=UTC;
DLTime=false;Units=ft
CE42AAD0.PP.RZZ.1001=ACIA-Atlantic-East Nishnabotna.Precip.Inst.0.0.$Stream-raw;TZ=UTC;
DLTime=false;Units=in
```

2. On-the-fly transformation/validation: This file is used for the on-the-fly validation and transformation of data before it is stored into the CWMS Oracle database. The data is checked for absolute magnitude (minimum and magnitude). If applicable, a flow or storage is also assigned to the respective stage or elevation (see example). Note that there currently is no way to include a rating curve shift option.

```
Key = ACIA-Atlantic-East Nishnabotna.Stage.Inst.0.0.$Stream-raw
AbsMagQuestion = 0.1,21.0
AbsMagReject = 0.1,34.0
Store = ACIA-Atlantic-East Nishnabotna.Stage.Inst.0.0.$Stream-raw;Units=ft
Lookup = $CWMS_HOME/config/da/comb/trn/rating.dss:/NISHNABOTNA/ACIA/STAGE-
FLOW//01JAN93/USGS-#14/
Store = ACIA-Atlantic-East Nishnabotna.Flow.Inst.0.0.$Stream-raw;Units=cfs
```

3. Extract from Oracle to HEC-DSS: This file is used to extract the data previously stored in Oracle to the HEC-DSS file rawdata.dss (see example). Note that each stream needs to be identified separately.

```
ACIA-Atlantic-East Nishnabotna.Stage.Inst.0.0.$Stream-raw=/NISHNABOTNA/ACIA/STAGE//IR-
MONTH/RAW-$Stream/;Units=ft;Type=INST-VAL
ACIA-Atlantic-East Nishnabotna.Precip.Inst.0.0.$Stream-raw=/NISHNABOTNA/ACIA/PRECIP//IR-
MONTH/RAW-$Stream/;Units=in;Type=INST-CUM
```

4. DATCHK criteria: This file is used to check the raw data for absolute magnitude levels and also compare the data to the previous data for rate-of-change levels (see example):

```
CRITERIA ABS R .01 21
CRITERIA ABS Q .01 34
CRITERIA RATE Q -.8 +.8
ESTIMATE RM LINEAR 10
PRECISION 2
DATA $CWMS_HOME/dated/da/comb/rawdata.dss:/NISHNABOTNA/ACIA/STAGE//IR-MONTH/RAW-
MRRDRGS/; $CWMS_HOME/dated/da/comb/middata.dss: F=REV-MRRDRGS
DATA $CWMS_HOME/dated/da/comb/rawdata.dss:/NISHNABOTNA/ACIA/STAGE//IR-MONTH/RAW-
NWKLGRS/; $CWMS_HOME/dated/da/comb/middata.dss: F=REV-NWKLGRS
DATA $CWMS_HOME/dated/da/comb/rawdata.dss:/NISHNABOTNA/ACIA/STAGE//IR-MONTH/RAW-
NWODATAWISE/; $CWMS_HOME/dated/da/comb/middata.dss: F=REV-NWODATAWISE
DATA $CWMS_HOME/dated/da/comb/rawdata.dss:/NISHNABOTNA/ACIA/STAGE//IR-MONTH/RAW-
NWODOMSAT/; $CWMS_HOME/dated/da/comb/middata.dss: F=REV-NWODOMSAT
```

Future additions for the Oracle master table will include creating 1) a DSSMATH macro to combine the data for each station from the four data streams into one “combined” stream, 2) validation files used to validate the combined data using the CWMS Control And Visual Interface (CAVI), 3) a DSSMATH macro to assign discharges and storages to stages and elevations, respectively, using current rating curves and shifts, and 3) a posting file that indicates all the final edited and transformed data to be posted to the CWMS Oracle database.

This Oracle master station table will prove especially valuable during flooding events. In 1997, record snowfall in the Missouri River Basin caused the need for additional gages to monitor runoff during the spring snowmelt. Various Federal, state and local agencies installed numerous real-time monitoring stations throughout the

region. The amount of time needed to ensure that the raw data was collected, decoded, transformed, verified, and posted for agency and public dissemination could have been considerably reduced had the offices had access to such a master station table. Figure 2 outlines the steps needed for the raw GOES data to be processed and posted for agency and public dissemination.

#### **E. Betterments**

Several water control offices in the Northwestern Division are working collaboratively on several CWMS betterments. The purpose of these betterments is to increase the efficiency of the data processing and simplify the data transformation. The goal is to take advantage of all the software that the Corps currently uses (e.g. Microsoft Word and Excel, Oracle, Apache, browsers) and integrate them.

The first betterment involves loading rating curves and measurements directly into the CWMS Oracle database instead of using HEC-DSS. Currently in the Omaha District CWMS production Oracle database, it takes 8 minutes for 600+ parameters to be extracted from Oracle to the HEC-DSS file “rawdata.dss”. Once in HEC-DSS, it takes approximately 4 minutes for the data to be validated, edited and transformed (e.g. stage to discharge and elevation to storage). It then takes another 8 minutes for the edited, and transformed data to be posted from the HEC-DSS file “revdata.dss”. At best, it takes 22 minutes for a piece of raw data to be initially captured, decoded, and processed to a point where the flows and discharges can be used for modeling, bulletin, or briefing purposes. Under normal, non-flooding circumstances this time lapse is generally acceptable; however, during flooding circumstances, 22 minutes may be too long a period to wait. Saving the storage and rating curves and measurements directly in the CWMS Oracle database will allow for storages and flows to be assigned directly after the data is processed through a soon-to-be-developed on-the-fly transformation and validation procedure in Oracle.

The second betterment involves utilizing Oracle’s web-based dissemination tools to display, edit, enter, and save data directly into the CWMS Oracle database. The biggest advantages of this betterment is that it offers web browser capabilities for 1) greater flexibility in creating bulletins for agency and public dissemination, 2) an easy method for field input of data, and 3) almost instantaneous verification of data updates.

#### **F. COOP Plan**

Development of the MRR COOP plan (which includes the NWO and NWK water control offices) continues to evolve as each office continues its efforts in fully implementing CWMS as its production database. The COOP plan provides guidance on the water management software restoration for emergencies, disasters, mobilization, and maintenance of a state of readiness to provide the necessary level of information processing support commensurate with the mission requirements/priorities identified by the functional proponent. The water

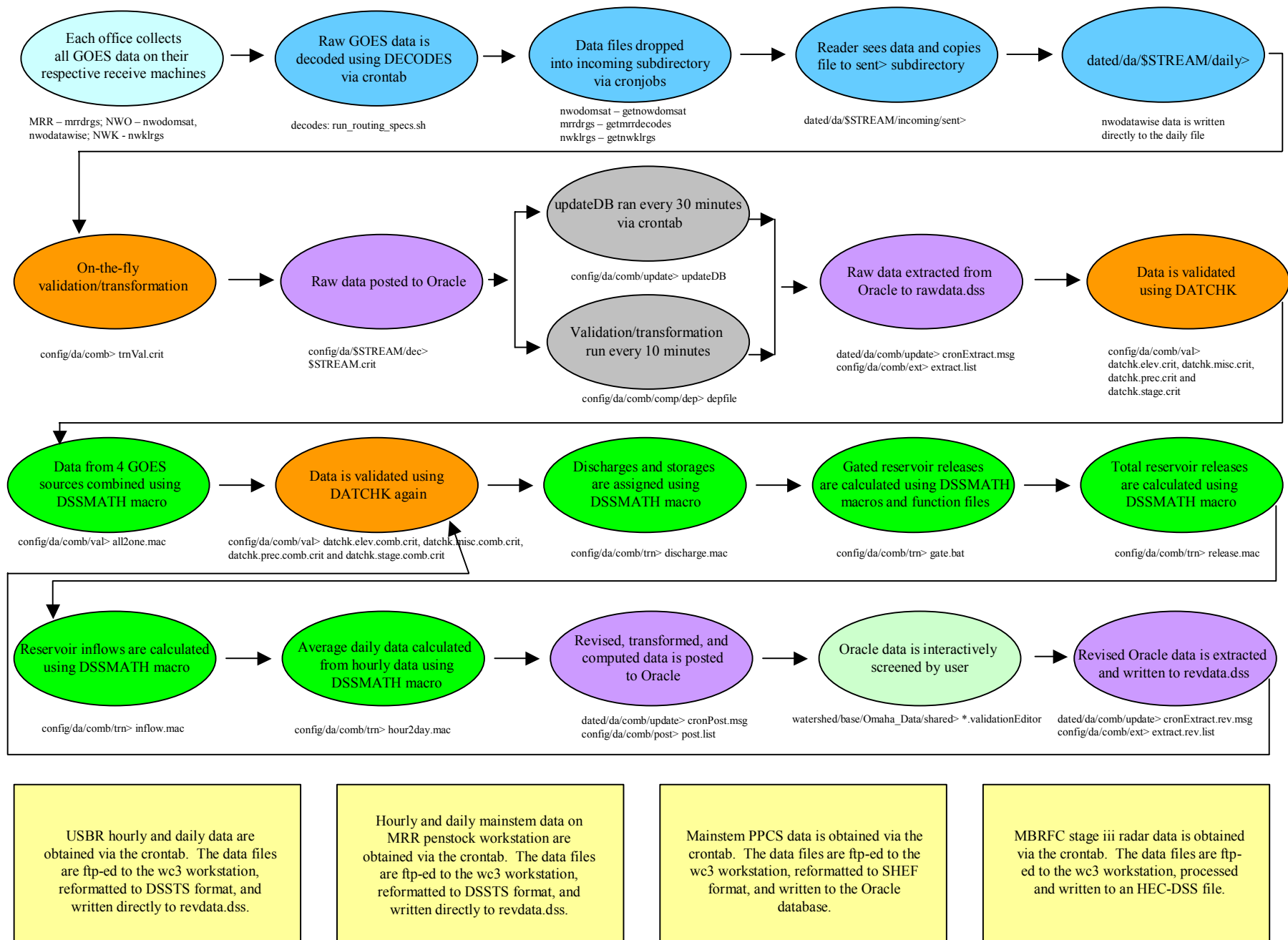


Figure 2 – Flowchart of Data Processing in CWMS

management COOP is written to serve as a living document to identify, describe, and plan for failures of the water control system by natural or unnatural occurrences or catastrophic events.<sup>2</sup>

Regarding implementation of CWMS for COOP purposes in the Missouri River Basin, each office 1) is collecting DCP data from each of the three offices' data collection workstations, 2) will have a complete on-the-fly transformation/validation file, and 3) will have a complete (and daily updated) set of decodes, rating curves, measurements, and storage curves. In a worst case scenario when all network Local Area Network (LAN) capabilities have been severed, a procedure has been written that will allow for the CWMS Oracle database to be bypassed. The data can be accessed straight from the data collection machine and physically transferred to a SUN-unix workstation where it can be decoded, stored directly to a HEC-DSS file, and then processed and used for real-time water control decision-making purposes.

### **G. Summary**

The three water control offices in the Missouri River Basin are currently implementing CWMS as a regional corporate database. The offices have separate, but connected, regulation responsibilities. The implementation of CWMS in the Missouri River Basin encompasses the acquisition of GOES and non-GOES data, the decoding of GOES data, storing, editing, and transformation of data and sharing of real-time model results. In addition, a master station Oracle database is being developed to simplify the addition, deletion and/or changing of station information within the CWMS Oracle database. Finally, the implementation of CWMS in the region will incorporate the basic tenants of the accepted Corps' COOP.

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<sup>1</sup>Hydrologic Engineering Center, U.S. Army Corps of Engineers, CWMS Enterprise Management Plan, 8 August 2002.

<sup>2</sup>U.S. Army Corps of Engineers, Continuity of Operations Plan for Missouri River Water Management Office Local Operation and Recovery, Preliminary Draft, 31 January 2002.